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Alan C. Stockman

Linda L. Tesar

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ABSTRACT

This paper studies the international transmission of business cycles by developing a two-country real business-cycle model and confronting it with a broad set of empirical observations. These observations include variances and covariances of output, labor, consumption, employment, and investment in traded and nontraded sectors of the economy, cross-country correlations of output and consumption, and correlations between quantities and relative prices. We find that technology shocks as measured by observed total factor productivity (by sector) must be supplemented by other sources of disturbances to explain certain features of the data. We call these other disturbances taste shocks, though they may stand in for some other shocks. In particular, it is difficult to explain the observed comovements of the relative price of nontraded to traded goods with the relative consumption of those goods without invoking something like taste shocks. Our model is roughly consistent with a broad set of observations, though puzzles emerge regarding the correlation of nontraded-sector output with its relative price and the variance of the balance of trade.

Alan C. Stockman
Department of Economics
University of Rochester
218 Harkness Hall
Rochester, NY 14627

Linda L. Tesar
Department of Economics
University of California
2127 North Hall
Santa Barbara, CA 93106

Tastes and Technology in a Two–Country Model of the Business Cycle: Explaining International Co–movements

Alan C. Stockman

Linda L. Tesar

1. Introduction

This paper develops a two–country real business cycle model and confronts the model with an extensive set of empirical observations. In particular, we examine the model's consistency with the behavior of international as well as domestic variables, the cyclical behavior of relative prices and the model's implications for economic aggregates at the sectoral level. This line of research is motivated by a desire to understand the international transmission of business cycles and changes in international competitiveness as reflected in the behavior of relative prices, such as real exchange rates and the terms of trade. We also hope to extend our understanding of business cycles in closed economies by studying a broader and different set of observations.[1]

Studies of cyclical fluctuations in a closed economy setting have identified several pervasive features of the business cycle: investment, consumption and work effort are strongly procyclical, investment is more volatile than output, and the time–path of consumption is generally smoother than that of output. These observations characterize business cycles not only in the United States but also in the larger set of industrial countries (see Dellas 1986, Backus and Kehoe 1988, Gerlach 1988, Baxter and Stockman 1989, and this paper, Section 2).

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[1]We hope to extend this research in the future to explain *differences* in business cycles across countries; some of these differences are apparent in the data tables in this paper.

These closed–economy features of business cycles have received much attention in the literature. However, there are several open–economy features of the cycle that a model of the international transmission of business cycles should explain. In Section 2, we discuss these open–economy aspects of the business cycle and present evidence on the cyclical behavior of the trade balance, the current account, the correlation between savings and investment, and the cross–country correlations of consumption, output and changes in productivity.

Disaggregation of the standard one–sector real business cycle model into a two–sector model with production of traded and nontraded goods helps to account for some of these international observations; in particular, the incorporation of nontraded goods helps to explain the low cross–country consumption correlations and the high correlation between savings and investment (Tesar, 1990). This disaggregation also introduces a number of new dimensions for evaluating the model.[2] Thus, we present evidence on the cyclical behavior of consumption, output, investment and work effort in the traded– and nontraded–good producing sectors and examine the correlations between these variables across sectors.

Finally, we confront the model with data on prices as well as quantities including the terms of trade, the real exchange rate and the relative price of nontraded goods. Some theoretical models of exchange rates (Stockman, 1980, 1987; Lucas, 1982) suggest that real disturbances like those emphasized in real business cycle models are the main cause of changes in real (and nominal) exchange rates. Our current paper attempts to provide the foundations of a quantitative analysis of neoclassical international finance that integrates equilibrium models of exchange rates with neoclassical models of business cycles and their international transmission.

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[2]This paper does not formally test hypotheses about the model, because the model is clearly false in ways that will become apparent. Our research is instead intended to describe the areas of success and failure of a simple neoclassical model, which we consider a necessary step to further theoretical and empirical analysis.

The empirical evidence is summarized in Section 2. We then describe our basic two–sector, two–country, neoclassical model in Section 3. In Section 4 we discuss calibration of the model[3] and the implications of the model when it is subjected to productivity shocks as measured by Solow residuals.

We find that when the basic model is driven by technology shocks or Solow residuals, it has several implications that are glaringly at odds with empirical observations. Although the model performs quite well in most dimensions, it fails to replicate observations on the correlation of consumption across countries and the co–movements of prices and quantities. We argue that the model cannot satisfactorily account for those observations without a different source of exogenous disturbances — disturbances that look much like shocks to tastes (or possibly shocks to fiscal policies which have similar effects).

When the model is extended to include random shocks to preferences in Section 5, we find that most of these glaring inconsistencies with the data vanish.[4] Though there are some features of the data that the model cannot explain, in an overall sense the model is consistent with most of the empirical evidence. We conclude from this study that shocks to technology *and tastes* (or something essentially equivalent) are required to explain the main features of business cycles and their international transmission. This paper shows some of the characteristics that such taste shocks must have in order to successfully match the data. The paper also highlights some interesting puzzles that should be the focus of future research.

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[3]We calibrate the model and simulate it to study its main areas of consistency or inconsistency with empirical observations. While the model turns out to be remarkably successful in most ways, there are several places where it clearly misses some important element. As a result, we do not formally estimate or test hypotheses about the model; that is reserved for the future after additional theoretical work and model development.

[4]Benzivenga (1987) has previously studied taste shocks in a real business cycle model. Benhabib, Rogerson and Wright (1990a,b) have recently studied a real business cycle model with "productivity" shocks to household production, which are very much like shocks to preferences.

2. Empirical Regularities

We focus attention on annual data for the seven largest industrial countries: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. A major source of our data is the International Sectoral Data Base compiled by the OECD. We also draw on data from the OECD Main Economic Indicators and the OECD Quarterly Accounts. A complete description of the data sources appears in Appendix A.

All empirical estimates referred to in the text of the paper are based on data detrended using the Hodrick–Prescott filter. Results based on data filtered by first–differencing appear in Appendix B. To get a sense of the effect of applying the Hodrick–Prescott filter, Figures 1 and 2 show the raw time series and the Hodrick–Prescott–filtered time series of United States output of traded and nontraded goods.

The International Regularities

There are several features of the data a model of the international transmission of business cycles should explain. First, the correlation of output growth across countries is large and positive. Part A of Table 1 shows the cross–country correlations of output based on data detrended using the Hodrick–Prescott filter: the top number in each element of the table shows the correlation between aggregate output in the two countries, the middle number shows the cross–country correlation between traded–good outputs, and the lower number shows the correlation between nontraded–good outputs. The correlations between aggregate outputs are positive and range from 0.437 between Canada and Japan to 0.858 between the United States and Germany, with an average of 0.69. The sectoral correlations are slightly lower on average than the aggregate correlations.

Second, the cross-country correlations of consumption are positive but are generally smaller than the cross-country correlations of output. Table 2 reports cross-country correlations of consumption based on data from International Financial Statistics (IFS) published by IMF and data reported by the OECD. Despite the high correlations between output growth rates across countries, the correlations between consumption growth rates are surprisingly low, particularly in the IFS data. In the OECD data, the correlation between aggregate consumption ranges from 0.028 between the United States and France to 0.882 between Japan and France; the average is 0.50.[5] The cross-country correlation between consumptions of nontraded goods is smaller on average (0.30) than that between consumptions of traded goods (0.42), though on a country-by-country basis this ordering is sometimes reversed.

The low cross-country correlations of consumption pose a problem for two-country neoclassical models which assume that financial markets are well integrated. In many such models (with complete markets and without distortions), consumption is perfectly (or nearly perfectly) correlated across countries. Backus, Kehoe, and Kydland (1989) study a one-sector, two-country model in which consumption is imperfectly correlated across countries because leisure and consumption are good substitutes in utility. In this setting a persistent productivity shock in the home country raises the domestic marginal product of labor and reduces leisure. Because leisure and consumption are substitutes, equilibrium consumption in the home country rises more than in the foreign country (or falls less), breaking the close link between foreign and domestic consumption. This is one of several mechanisms that break the link between home and foreign consumption in our model. The fact that consumption is less closely correlated across countries than is output is related to the much-discussed positive relation

[5]In Part B of Table 2, the top figure in each cell is the cross-country correlation between aggregate consumptions, the second between private final consumptions, the third, consumption of traded goods and the fourth, consumption of nontraded goods.

The first column of Table 4 shows the well–documented, strongly positive correlation between savings and investment. The last two columns of Table 4 show the correlations of the terms of trade with output and the trade balance. These relations are mixed, appearing to be strongly positive in some cases and strongly negative in other cases.

A summary of the relationships between the real exchange rate and consumption, output and the trade balance appears in Table 5. We define the real exchange rate as the ratio of the home consumer price index to the foreign consumer price index.[10] There appears to be no consistent co–movement between these macroeconomic aggregates and the real exchange rate.[11] Table 6 reports standard deviations of the terms of trade, the consumer price index, the trade balance and the current account.

The presence of nontraded goods provides part of the explanation for the cyclical behavior of some of these international variables. Consumption of nontraded goods breaks the strong link between foreign and domestic consumptions and contributes to the countercyclical behavior of the trade balance. Nontraded capital goods help to explain the strong link between domestic investment and national savings (Tesar, 1990a). This disaggregation also introduces a number of new dimensions for evaluating the usefulness of our model.

Empirical Regularities Within Countries

Perhaps the most striking feature of the data of the seven industrialized countries is the large share of nontraded goods in the economy. Following Kravis, Heston and

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[10]The rows of Table 5 refer to the output (consumption or trade balance) of country i while the columns are the real exchange rates, defined as the ratio of the consumer price index of country i to that of country j.

[11]It is difficult to draw conclusions about the cyclical behavior of the terms of trade and the real exchange rate in either Hodrick–Prescott filtered data or first–differenced data. However, it may be possible to use the results from specific countries in a study calibrated to a particular pair of countries.

Summers as closely as possible, we categorize the ten sectors reported by the OECD Intersectoral Data Base into traded and nontraded industries. Table 7 shows the sectors included in the two categories and reports the share of each of the ten sectors in 1984 GDP. Nontraded goods account for about *half* of output.[12] This corresponds closely with the share of 52 percent reported by Kravis, Heston and Summers for their ten–country sample of industrialized countries.[13]

Table 8 shows the standard deviations of output, the capital stock, work effort, investment and the estimated Solow residuals. Part B of the table shows the standard deviations of these series relative to the standard deviations of output in each sector. The standard deviations of the Solow residuals in each industry are approximately the same magnitude as the standard deviations of output in that industry, and are higher in the traded than in the nontraded sector. Investment is two–to–three times as variable as output in most countries and in both industries, while labor is less variable than output. Interestingly, fluctuations in the capital stock appear to be much larger in the nontraded–good producing industry than in the traded–good producing industry.[14]

The shares of nontraded goods in private final consumption in the seven OECD countries are shown in Table 9. We estimate the share of nontradables in private final

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[12]A good case can be made that most retail services — retail and wholesale trade, and services of restaurants and hotels — should be considered nontraded goods. We include value added of retail and wholesale trade in the traded–good category to be consistent with Kravis, Heston and Summers. They do, however, treat restaurants and hotels as nontraded goods. They are included in our measure of traded goods because the data are not reported for all countries and the share of restaurants and hotels in total GDP is small enough (less than three percent of GDP) that this should have little effect on the overall results. Kravis, Heston and Summers also treat public transportation and communication as nontraded goods. We treat them as traded goods because we lack data to separate these categories from private automobile purchases, which are the largest component of the transportation category.

[13]See World Production and Income, Table 6–10, p.194.

[14]Note that this is true of the capital stock series but not generally for the investment seres. This may be due to the method used by the OECD to estimate the gross capital stock from investment time series. In assessing the simulation results, we will focus on the investment data rather than the capital data.

consumption in two ways. One estimate treats services and nontraded goods as equivalent. The second measure is based on a breakdown of private consumption expenditure by type, following as closely as possible the decomposition specified by Kravis, Heston and Summers (1985). When services are used as a proxy, the data indicate that nontradables are a large and growing component of consumption. By the 1980s, services accounted for roughly 50 percent of private final consumption, while the second measure of nontradables indicates a share closer to one-third.[15] The second measure is a smaller number because several of the categories considered by Kravis, Heston and Summers to be nontradables are not reported by the OECD.[16] The measure for the United States is based on data from CITIBASE, which includes all of the relevant categories (see note [f] in the table), is consistent with the measure based on services.

Finally, the standard deviations of consumption by sector are provided in Table 10. For five of the six countries, consumption of the traded good appears to be more volatile than consumption of nontradables. Interestingly, a comparison of the data in Tables 10 and 8 suggests that consumption of traded goods is nearly or, in some cases, even more volatile than output of traded goods.

The large proportion of nontraded consumption and output in the economy is consistent with the relative importance of trade in these economies. On average, trade is about twenty percent of aggregate output (see Table 11). In contrast, a simple

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[15]One problem with using services as a proxy for nontradables is that trade in some types of services has been increasing. In the United States there is evidence that trade in services has expanded at a rate faster than the increase in output of services. However, most services were generally nontraded in the sample covered by this paper.

[16]The second measure of nontradables includes the categories "rent, fuel and power" and "transportation and communication" reported by the OECD. To the extent transportation includes the purchase of automobiles, inclusion of this category clearly overstates the importance of nontradables in private consumption. However, since the other categories included in the Kravis–Heston–Summers definition of nontradables are unavailable, we believe the overall figure underestimates, rather than overestimates, the share of nontradables in consumption.

model in the tradition of Lucas (1982), abstracting from nontradables, would predict that trade is half of output. Investment is approximately twenty percent of output.

The inclusion of nontraded goods in our theoretical model allows us to consider the co–movements of variables across sectors over the business cycle. The third column of Table 12 shows the correlations between the price of nontraded goods (relative to traded goods) and the ratio of consumption of nontraded to traded goods. We find the correlation to be negative with the six–country average at –0.42.[17] The magnitude of this correlation will prove to be a problem for the model based on productivity shocks alone: in such a setting, an increase in productivity causes an increase in consumption of the good and a large fall in its relative price. The small but positive correlation between the relative price of nontraded goods and the relative output of nontraded goods runs counter to models based on productivity shocks or on taste shocks. Table 12 also reports a strongly positive correlation between consumptions and outputs across sectors.[18]

3. A Two–Sector, Two–Country Model

In this section we develop a two–sector, two–country model to account for the cyclical properties of the data outlined in Section 2. Our research builds on the work in several recent papers on international real business cycles (Dellas 1986, Backus, Kehoe, and Kydland 1989, Ahmed, Ickes, Wang, and Yoo 1989, Schlagenhauf 1989, and Baxter and Crucini 1990).

In this paper, countries are assumed to be linked via trade in some types of consumption goods and trade in financial assets. The model is based on Lucas (1982)

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[17] The corresponding number for data using the growth–rate filter is –0.2.

[18] Table B9 in Appendix B shows the correlations between consumption and investment with output in Hodrick–Prescott filtered data and in first–differenced data. Table B10 shows the correlation between (Y/Y^*) and (P/P^*) for both filters. Some of these data will be used in evaluating the simulation results.

lifetime (contingent) plan of consumption and work effort to maximize its expected lifetime utility subject to a wealth constraint:[19]

$$\beta^t E_t \sum_{t=0}^{\infty} u(c_{1t}, c_{2t} d_t, L_t). \tag{3.7}$$

In a similar way, the representative consumer in the foreign country chooses plans for $\{c_1^*, c_2^*, d^*, L^*\}$ to maximize lifetime utility subject to its wealth constraint.

In equilibrium the world supply of each good must be exhausted by world consumption and investment demand for each good. In the market for the home-produced traded good, output must be equal to consumption of the home good in the two countries, plus investment of the good in next period's production:

$$Y_t^T = C_{1t}^T + C_{1t}^{T*} + I_t^T. \tag{3.8}$$

Equation (3.8) is the symmetric market clearing condition for the foreign-produced traded good:

$$Y_t^{T*} = C_{2t}^T + C_{2t}^{T*} + I_t^{T*} . \tag{3.9}$$

The equilibrium conditions for the nontraded good industries require that the domestic supply of the good be exhausted by domestic consumption and investment demand:

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[19]We assume that the household faces a complete contingent claims market. More specifically, contracts can be written contingent on outcomes in both the traded- and nontraded-good industries, which allows the household to insure *partially* against fluctuations in leisure and in the local supply of nontraded goods. The household's wealth constraint has the obvious form for complete contingent markets. Rather than solving for the equilibrium directly, we solve a social planning problem corresponding to the competitive equilibrium in which the countries are assumed to have equal wealths.

$$Y_t^{NT} = d_t^{NT} + I_t^{NT} \tag{3.10}$$

$$Y_t^{NT*} = d_t^{NT*} + I_t^{NT*} . \tag{3.11}$$

We can solve for the equilibrium allocations of consumption, leisure, work effort and capital inputs by considering the problem facing a social planner who maximizes the expected lifetime utilities of the two representative agents subject to world market–clearing conditions. That is, the planner chooses the levels of consumption and investment of each good to maximize:

$$\max \beta^t E_t \sum_{t=0}^{\infty} [\omega\ u(c_{1t},c_{2t},d_t,L_t) + (1-\omega)\ u(c_{1t}^*,c_{2t}^*,d_t^*,L_t^*)] \tag{3.12}$$

subject to equations (3.7) through (3.10). The multiplier on the home country's utility function, ω, is the home country's share of world wealth. We abstract from effects deriving from differences in country size or wealth by setting ω equal to one–half.[20]

The disturbances to technology are assumed to follow an AR(1) process:

$$A_{t+1} = \Omega A_t + \epsilon_t \tag{3.13}$$

where A is the vector $[A^T, A^{NT}, A^{T*}, A^{NT*}]$ and Ω presents a 4x4 matrix describing the autoregressive component of the disturbance. The contemporaneous component of the shock is described by the vector $[\epsilon^T, \epsilon^{NT}, \epsilon^{T*}, \epsilon^{NT*}]$. The variances of the

[20]Agents are assumed to trade contingent claims to pool the world supply of traded goods. National savings (abstracting from capital gains and losses) in the home country are defined as:

$$S_t = P_t(\omega\ Y_t^T - c_{1t}) + P_t^{T*}(\omega\ Y_t^{T*} - c_{2t}) + P_t^{NT}(Y_t^{NT} - d_t).$$

Following Kravis and Lipsey (1987, footnote 12, p.130), we estimate the elasticity of substitution between traded and nontraded goods from the cross-sectional data provided in the World Bank's Income Comparison Project.[23] We find that there is a low degree of substitutability in consumption with an elasticity of substitution $[1/(1+\mu)]$ of 0.44. The rate of time discount is set equal to 0.96 and the intertemporal elasticity of substitution $(1/\sigma)$ is set equal to 0.5.[24] The intertemporal elasticity of substitution in leisure (1/a) is set equal to –3.173, which is consistent with a steady–state allocation of twenty percent of the time endowment to work effort and eighty percent to leisure.

These parameters determine the steady–state shares of consumption and investment in output of the two goods. The remaining parameter value to be chosen is the share of domestic goods in the domestic consumer's total consumption bundle. This share is difficult to estimate directly from the data; however, under the assumption of complete specialization, the share can be inferred from data on trade flows between the industrialized countries. As discussed in Section 2, since investment is about 20 percent of GDP, about half of investment is allocated to the nontraded–good industry, and nontraded goods are about half of GDP, 40 percent of GDP remains for consumption of traded goods. With perfect pooling of traded goods, this implies that trade is 20 percent of GDP, which is consistent with the data. The volume of trade implied by our model is:

$$\frac{\text{Trade}}{\text{GNP}} = (1/2)\theta(1-s_i^T) \tag{4.3}$$

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[23]We calculate the elasticity of substitution between traded and nontraded goods in a sample of thirty countries using data on per capita GDP (World Product and Income, p.12), expenditure shares on traded and nontraded goods (ibid, p.194) and price indices for traded and nontraded goods (ibid, p.196).

[24]Different values of σ result in the expected changes in aggregate consumption and investment behavior but have little impact on the features of the data studied here.

where "trade" is defined as the average of exports plus imports and s_i^T is the investment share in total output of the domestic traded good. Referring back to Table 11, the bottom rows of the table indicate the trade flows implied by different trade shares. Interestingly, a share equal to 0.5, i.e. equal shares of the home traded–good and foreign–traded good in each countries' consumption bundle, has the closest fit to the volume of trade in these countries.[25]

The technology shocks to the two industries display a low degree of persistence when calculated from Hodrick–Prescott filtered data.[26] The estimated autocorrelation matrix for the vector of shocks $[A^T_, \; A^{NT}_, \; A^{T*}_, \; A^{NT*}]$ is:

$$[\Omega] = \begin{vmatrix} .154 & .040 & -.199 & .262 \\ -.015 & .632 & -.110 & .125 \\ -.199 & .262 & .154 & .040 \\ -.110 & .125 & -.015 & .632 \end{vmatrix} \tag{4.4}$$

The degree of autocorrelation is quite low, especially in the traded–good industry. The estimated variance–covariance matrix of the contemporaneous component of the shock is:

$$V[\epsilon] = \begin{vmatrix} 3.62 & 1.23 & 1.21 & 0.51 \\ 1.23 & 1.99 & 0.51 & 0.27 \\ 1.21 & 0.51 & 3.62 & 1.23 \\ 0.51 & 0.27 & 1.23 & 1.99 \end{vmatrix} \tag{4.5}$$

The disturbances to the traded–good industry are nearly twice the magnitude of the shocks to the nontraded–good industry. There is little evidence that disturbances are

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[25]Our model does not address the fact that the share of trade in GDP has been growing over time in most countries but treats the volume of trade in output as a constant. Our model does, however, suggest that in the presence of nontraded goods and specialized production, the long–run share of trade in output is likely to level off at a number significantly less than one–half.

[26]The estimated autocorrelation and variance–covariance matrices based on data that are log–linear detrended are reported in Appendix D.

readily transmitted abroad nor is there evidence that industry–specific disturbances are more prominent than country–specific disturbances. The correlation between innovations to the traded–good sectors in the two countries is 0.33 while the correlation between innovations to the nontraded–good sectors is 0.14. Country–specific innovations (across sectors within a country) appear to be slightly more significant, with a cross–sector correlation of 0.46.

The results of simulations of the model given these disturbances to technology are shown in Table 14. The numbers in the column labelled "Data" are five–country averages of the standard deviations or correlations presented in the tables in Section 2. We will evaluate our model in terms of these cross- country averages. A centered 95–percent confidence interval for those data appear in brackets.[27]

The results marked Case 1 show the implications of the model driven by Solow residuals as technology shocks. The standard deviations of aggregate variables match the data fairly closely, though the standard deviation of consumption is only three–fourths its size in the data (though well within the centered two–standard–deviation band). The standard deviations of traded–good aggregates indicate two types of problems: investment in the traded–good sector is roughly thirty percent too volatile and the standard deviation of consumption is much too small: it is only one–third of its mean in the data. The standard deviation of output of nontraded goods is larger in the model than in the data, while the standard deviation of consumption of nontraded goods is again well below its mean in the data. In general, the model matches the standard deviations of the data reasonably well except that the model implies a much lower variability in consumption than appears in the data.[28]

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[27]These intervals ignore sampling error in estimating the moments reported in the earlier tables. The cases with asterisks are cases in which an outlying observation has been omitted.

[28]Taste shocks are an obvious potential soluction to this problem, as we demonstrate below.

The model delivers a good approximation of the correlation between consumption and output, though it overpredicts the correlation between investment and output. It also matches the correlation between consumption of traded and nontraded goods. While it implies a correlation of output in the two sectors that is smaller than the mean in the data, the figure implied by the model is within the two–standard–deviation band.

Table 14 also shows that the correlation between the aggregate average product of labor (APL) and output is, on average for the 5–countries, .76. This correlation ignores variation in hours worked, so it overstates the appropriate correlation by about 10–percent.[29] The model implies a correlation of .69, so the model matches this feature of the data. This is an important result because the correlation implied by most closed–economy real business–cycle models is too high to match the data.

The model fails when it is confronted by price data. The model predicts that the correlation between the relative price of nontraded (to traded) goods and the relative consumption of nontraded (to traded) goods is *minus one*; it is –0.42 in the data, with a two–standard–deviation band between –.12 and –.71. The technology shocks driving the model act mainly as relative supply shocks, leading to shifts in supply curves along

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[29]The .76 correlation (which is a five–country average) is above the .33 correlation for the U.S. shown in Prescott (1986) for several reasons. First, Prescott excludes farm labor, though farm output is included in output. Second, we use a longer sample. These changes alone raise the U.S. correlation from .33 to .52. Third, our Table 14 reports statistics on annual rather than quarterly data. For the U.S., this raises the correlation from .52 to .76. Fourth, we lack data on variations in hours, so our labor series is employment. In the U.S., using employment rather than total hours raises the correlation from .76 to .87. (At a quarterly frequency, it raises the correlation from .52 to .79). So, based on U.S. data, our use of employment rather than hours implies about a 10–percent overstatement of the correlation. Hours variation appears to be much more important relative to employment variation in the other countries in our sample, see e.g. Kennan (1987). So, because the labor input appropriate to our theoretical model is total hours, we would like to the model to imply a correlation no more than 10–percent smaller than the .76 correlation appearing in the Table 14, and ideally smaller than that. Though the model in Case 1 matches this 10–percent reduction, the other cases we discuss below imply smaller correlations which appear to be more consistent with the average experience in our sample.

rather stable (relative) demand curves. The data suggest a combination of shifts in the relative supply and the relative demand curves. The same problem arises in matching the correlation between the relative price and relative outputs of traded and nontraded goods.

In terms of the international data, the model does a good job of matching the correlation between aggregate output across countries. However, it overpredicts the cross–country correlation of consumption by more than fifty percent. The model slightly overstates the correlation between savings and investment but is within the two–standard–deviation band. The model does quite well at matching the correlation between output and the balance of trade, though it understates the countercyclical nature of the current account.[30] The model's predictions for the standard deviations of trade variables — the terms of trade, trade balance, and current account — are much too low.

Overall, the model driven by Solow residuals has several problems. One of these problems, the high cross–country correlation of consumption, was already known to be present in one–sector models. This observation motivated our disaggregation into traded and nontraded sectors; this disaggregation introduced a number of new dimensions for testing the model. While the disaggregated model provides more reasonable predictions for the correlation between consumptions across countries, the countercyclical behavior of the trade balance and the current account and the correlations between quantities across sectors, the model fails to predict the magnitude of the variability of consumption and the co–movements between quantities and prices.

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[30]The model's ability to produce strongly counter–cyclical movements in the trade balance and the current account is a direct consequence of the incorporation of nontraded–goods production and the complementarity between consumption of traded and nontraded goods. In one–sector models, the trade balance is generally found to be procyclical.

The next section shows that some, though not all, of these problems vanish if the model is subject to taste shocks as well as productivity shocks.

5. The Effects of Taste Shocks

Table 14 shows simulation results in which the model is subjected to six different kinds of taste shocks (labeled cases 2 through 7), as well as technology shocks. The economy is identical to the model in Section 4, except that the utility function is now

$$u(c_{1t},c_{2t},d_t,L_t) = \frac{1}{1-\sigma} [[((\tau_{1t}+c_{1t})^{\theta}(\tau_{2t}+c_{2t})^{1-\theta})^{-\mu} + (\tau_{3t}+d_t)^{-\mu}]^{-\frac{1}{\mu}}]^{1-\sigma}L_t^a$$

where τ (for i=1,2,3) is a positive random variable with mean zero representing a taste shock. There are three analogous taste shocks for the representative foreign household. We assume taste shocks are independent across countries, independent of technology shocks, and that the vector $\tau = (\tau_1,\tau_2,\tau_3)$ follows a first-order autoregressive process. Table 15 shows the matrix of autoregression coefficients and the covariance matrix of the disturbances in each case. The form of the taste shocks has a simple interpretation: a unit increase in τ_1 lowers marginal utility of good one by the same amount as would a unit increase in c_1.

Case 2 subjects the model to taste shocks for the home-produced traded good in addition to technology shocks. We assume that the variances of τ_1 and the corresponding taste shock in the foreign country (for their home-produced traded good), τ_1^*, are the same as the variances of the Solow-residuals for traded-good production. In this sense, Case 2 considers taste shocks that are of the same magnitude as the technology shocks. However, when the autocorrelation matrix of taste shocks is set equal to that for technology shocks, the standard deviations of consumption remain much too low in the model relative to the data. Therefore the figures reported for Case 2 correspond to taste shocks with an autocorrelation of 0.9 (per year).

Adding these taste shocks for home–produced traded goods raises the standard deviation of consumption of traded goods to about its size in the data. It also raises the standard deviation of labor in the traded sector. These shocks have little effect on the nontraded sector despite the complementarity between traded and nontraded goods in consumption. The taste shocks raise the correlation between the relative price and the relative consumption of nontraded goods from minus one to –0.45, which is much closer to the mean of the data. It also raises slightly the correlation between the relative price and relative output of nontraded goods. The taste shocks reduce the cross–country correlation of consumption in half, from 0.78, which was above the two–standard–deviation band, to 0.39, which is within that band. This kind of taste shock does not improve the model's performance for the standard deviation of the terms of trade or trade balance. However, it does raise the standard deviation of output to within the two–standard–deviation band of the data. Not surprisingly, the shock also results in a correlation between consumption of traded and nontraded goods that is too small.

Case 3 shows the results of making the taste shocks much smaller but more autocorrelated. In case 3, the variance of the taste shocks is one *one–hundredth* the magnitude of the traded–sector Solow residuals. The shocks are nearly permanent with an autocorrelation of .999. Interestingly, the results of case 3 are very similar to those of case 2.

Case 4 considers taste shocks for the nontraded good (along with technology shocks). As in case 2 we set the variance of the taste shocks for each good equal to the variance of the Solow residuals in that sector. We also set the autocorrelation of the taste shocks equal to that of the Solow residuals. In this sense, the taste shocks and technology shocks are the same size.

The nontraded–good taste shocks in Case 4 affect standard deviations mainly in the nontraded–good sector. The standard deviations of consumption and labor in that sector are closer to the mean in the data. The correlation between the relative price and relative consumption of nontraded goods rises from minus one to –0.54. The cross–country correlation of consumption falls but still remains above the mean in the data. The standard deviations of the trade variables are too low, the correlations of consumption and output across sectors are too low, and the standard deviation of consumption of traded goods is much too low.

Case 5 combines the taste shocks from cases 2 and 4 by setting the taste shocks for each good equal in size to the productivity shocks in the two sectors. Case 5 assumes these shocks are uncorrelated across sectors but are positively autocorrelated. The standard deviations of consumption — in the aggregate and in each sector — are now close to the mean in the data. The cross–country correlation of consumption is closer to its mean in the data as are the correlations of consumption, investment, the trade balance, and current account with output. The correlation of savings and investment also gets closer to its mean in the data. As in cases 2 and 3, the standard deviation of the current account is within the two–standard–deviation band in the data.

There are a number of problems with the combined shocks considered in Case 5. Aggregate labor is too volatile relative to the data, investment in the traded–good sector continues to be too volatile, the correlations of output and consumption across sectors are too small, the standard deviations of the terms of trade and trade balance are too small, and the correlation of the relative price of nontradables with relative output continues to be too small.

Case 6 repeats the pattern of taste shocks for both goods considered in Case 5 but makes these shocks more correlated across sectors. The contemporaneous correlation is set at 0.5. The primary result is an increase in the correlation of consumption across sectors. Otherwise the results are similar to Case 5.

Case 7 reduces the variance of the taste shocks in Case 5 to one one–hundredth of their size in Case 5, and adds higher autocorrelation. The results are better in some respects than in Cases 5 and 6, and not as good in other respects.

Impulse Response Functions:

The intuition for some of these results becomes more clear by studying the impulse response functions of macroeconomic variables following a one–time distubance to tastes and technology. Figures 3 through 6 show the dynamic responses of consumption, work effort and investment to a one–percent (above steady state) change in productivity and consumer preferences for traded and nontraded goods. Both types of shocks are assumed to die out at a rate of 20 percent per year (i.e. $\rho = 0.8$). The shocks occur only in the home country; the top graph shows the resulting dynamics in the home country and the bottom graph shows the response in foreign country.

Figures 3a and 3b show the responses in the two countries to a disturbance in the traded–good producing sector in the home country. At the time of the productivity disturbance, work effort in the traded–good sector rises in response to the higher marginal product of labor and then gradually decreases as capital investment in that sector rises. Consumers in both countries consume more of the home country's traded good and substitute away from the foreign country's traded good. Nontraded good consumption rises in both countries due to the complementarity between traded and nontraded goods.

When the productivity shock occurs in the nontraded–good sector (Figures 4a and 4b), the response of consumption is quite different. Consumption of the nontraded good rises in the home country along with investment of the nontraded capital good. Labor again shifts out of the high–productivity sector resulting in an increase in leisure and in greater effort in the traded–good sector. The consequent increase in output of the home-country's traded good leads to an increase in consumption of that good in both countries.

Figures 5a and 5b reveal that the dynamics following a taste shock are markedly different from the smooth bell-shaped curves following a productivity shock. The primary effects are on consumption and work effort; since the shock in these experiments is "unanticipated" and rapidly diminishes, there is no incentive for building up the capital stock to respond to the changes in demand. Work effort rises in the sector where the demand shift occurs and falls in the other sector. Interestingly, labor rises in the foreign country's traded-good sector: foreign consumers shift out of the now more expensive domestic traded good, increasing demand for their own traded good.

Figures 6a and 6b show the response to an increase in home demand for the domestic nontraded good. In this case, domestic consumers must increase domestic output of the nontraded good in order to meet demand. Work effort in the nontraded-good sector rises dramatically and falls in the traded-good sector. As a result, output of the domestically-produced traded good falls and consumption for the good decreases in both countries. Foreign country labor shifts into the traded-good producing sector as consumers substitute toward c_2 and away from c_1.

Overall, the results of these simulation experiments indicate that taste shocks improve the fit of the model. Of course, it is easy to improve the fit when there are free parameters to play with. However, the central issues are whether certain types of exogenous shocks, like taste shocks, are required to explain the data and, if so, what the nature of those shocks must be. It seems clear that some features of the data cannot be explained by the model with productivity shocks alone. Those shocks cannot explain the high standard deviations of consumption, the fact that the correlation between the relative price and relative consumption of nontraded goods is so far from minus one, or the low correlation between consumption across countries. Taste shocks, or something like them, seem to be required. These shocks may result from government policies rather than from changes in tastes, or they may result from changes in household production technology. The disturbances must affect mainly consumption, however, and not investment: investment is already volatile enough in the pure technology-shock model of Case 1.[31]

While we have shown that taste shocks of a particular form can improve the performance of the model along certain dimensions, there are three dimensions along which the model fares poorly. First, our model does not explain the high standard deviations of the terms of trade or balance of trade, though the model performs better for explaining that of the current account. Second, we have not explained the positive correlation between the relative price of nontraded goods and relative output (though the taste shocks help in this dimension). Third, the taste shocks we have added are not consistent with the observed high cross-sectoral correlations of consumption and output.

6. Conclusions

We have constructed and simulated a neoclassical macroeconomic model of a two-country world. The model matches most of the key features of the data. In particular, our model is consistent with the observations that the cross-country correlation of consumption is smaller than that of output and that the cross-country correlation of output exceeds that of Solow residuals. The model is also broadly consistent with the standard deviations of main economic aggregates and with those same variables in traded and nontraded-good sectors. The model is consistent with the

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[31]If what we have called taste shocks are really the results of fiscal or monetary policies, it appears that those policies must have their main effects on consumption rather than on investment!

correlations between aggregate output and investment, consumption, and the trade balance. It is also consistent with the correlation between the relative price and relative consumption of nontraded and traded goods.

To match the data, we required a model with shocks to *tastes* as well as technologies. The disturbances we have interpreted as taste shocks may actually result from shocks to technology in the household or fiscal or monetary policies. But we require *some* form of disturbances that, like taste shocks, act mainly as intersectoral demand–curve shifters in order to explain certain features of the data that cannot be explained by the technology– shock model.

There are, however, three main observations that out model does not explain: the intranational correlation between quantities in the traded and nontraded sectors, the correlation between relative quantities and relative prices in those sectors, and the standard deviations of the trade variables. The first two of the these observations deal with issues suggested by our disaggregation into traded and nontraded sectors. It appears that while some form of taste shock (or disturbance with similar effects) is required to explain the data, we have not yet identified the precise form that those shocks must take.

Figure 1: U.S. Output of Traded Goods - Hodrick-Prescott Filter

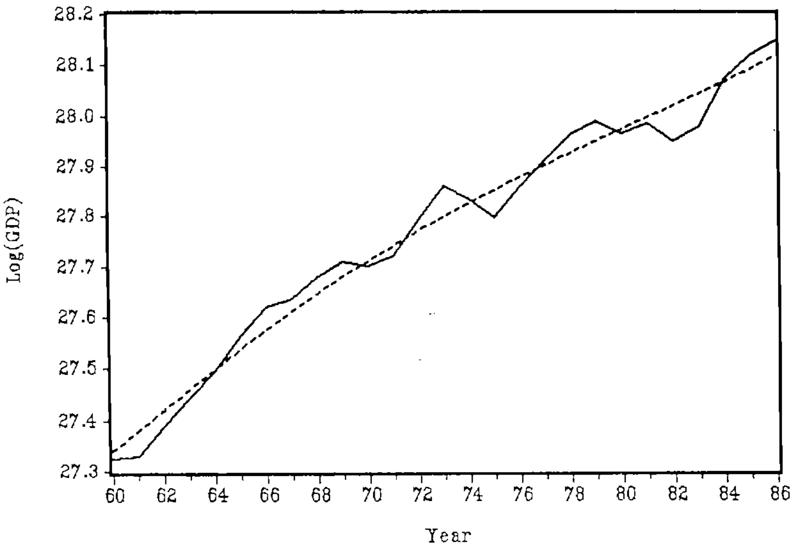


Figure 2: U.S. Output of Nontraded Goods - Hodrick-Prescott Filter

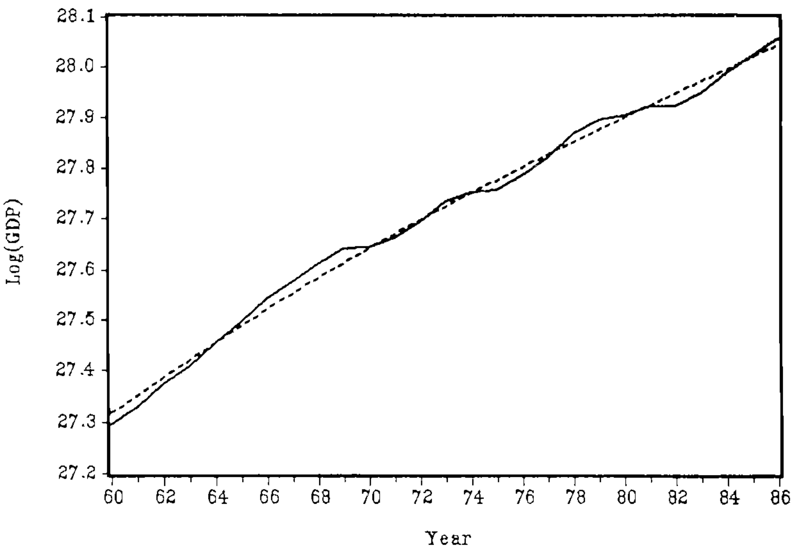


Table 1: **Cross–Country Correlations of Output and Productivity**

A. Correlations of Outputs (1971–1988)

	CANADA	JAPAN	GERMANY	ITALY
USA				
Agg	.679	.525	.858	.571
T	.737	.379	.839	.479
NT	.318	.530	.713	.623
CANADA				
Agg		.437	.694	.711
T		.468	.604	.563
NT		.363	.492	.645
JAPAN				
Agg			.618	.477
T			.344	.409
NT			.859	.501
GERMANY				
Agg				.835
T				.809
NT				.795

B. Correlations of Solow Residuals (1971–1984)

	CANADA	JAPAN	GERMANY	ITALY
USA				
Agg	.718	.441	.570	.454
T	.770	.092	.346	.193
NT	.546	–.212	.299	.704
CANADA				
Agg		–.017	.238	.329
T		.088	.245	.193
NT		.040	.304	.644
JAPAN				
Agg			.473	–.249
T			.275	.129
NT			.688	–.435
GERMANY				
Agg				.352
T				.417
NT				–.095

Source: Output and Solow residuals from OECD International Sectoral Data Base. All data are detrended using the Hodrick–Prescott filter.

Table 2: Cross–Country Correlations in Consumption

A. Correlations of Aggregate Consumption (1970–1988).

	CANADA	FRANCE	ITALY	U.K.
USA	.442	.103	–.581	.533
CANADA		.751	–.233	.295
FRANCE			.001	.025
ITALY				–.003

B. Correlations of Aggregate, Private Final Consumption, and Consumption o Traded and Nontraded Goods (1971–1987).

	CANADA	FRANCE	JAPAN	U.K.
USA				
	.348	.028	.235	.534
	.531	.359	.458	.595
	.417	.204	.140	.625
	.753	.503	.197	.412
CANADA				
		.754	.625	.485
		.744	.501	.329
		.614	.488	.476
		.624	.193	.075
FRANCE				
			.822	.419
			.808	.375
			.562	.458
			.412	–.079
JAPAN				
				.724
				.701
				.265
				–.067

Source: Part A is based on IFS annual data. Part B is based on data from the OECD Quarterly Accounts which are annualized by averaging. All data are detrended using the Hodrick–Prescott filter.

Table 3: **Average Labor Shares**

(Standard deviations in parentheses)

	Period	Aggregate	Traded	Nontraded
CANADA	1970–1984	.650 (.018)	.633 (.023)	.670 (.024)
FRANCE	1977–1989	.570 (.006)	.646 (.011)	.496 (.007)
GERMANY	1970–1985	.593 (.014)	.641 (.022)	.533 (.026)
ITALY	1960–1985	.500 (.047)	.482 (.061)	.529 (.027)
JAPAN	1970–1985	.530 (.038)	.544 (.044)	.513 (.033)
UNITED KINGDOM	1970–1985	.645 (.025)	.680[a] (.040)	.604 (.012)
UNITED STATES	1960–1985	.631 (.013)	.661 (.012)	.597 (.022)

Source: OECD International Sectoral Data Base.

a. Average for the period 1960–1985.

Table 4: **Correlations between Savings, Investment, Trade Balance, Current Account and Output**

	$Corr(\hat{S},\hat{I})$	$Corr(\hat{TB},\hat{Y})$	$Corr(\hat{CA},\hat{Y})$	$Corr(TOT^{a},Y)$	$Corr(TOT^{a},TB)$
CANADA					
60–88	.889	−.647	−.500	.298	.092
70–88	.896	−.714	−.547	−.315	.038
FRANCE[b]					
60–88	.860	.062	.080	−.384	−.335
70–88	.871	.208	.163	−.391	−.646
ITALY					
61–87	.472	−.444	−.787	.214	−.379
70–87	.430	−.257	−.719	.160	−.390
UNITED KINGDOM					
60–88	.669	−.515	−.537	.093	−.680
70–88	.630	−.523	−.540	.143	−.757
UNITED STATES					
60–88	.904	−.379	−.510	−.412	.589
70–88	.893	−.392	−.522	−.372	.588

Source: Columns 1, 2 and 3 from IFS annual data. The terms of trade are defined as the ratio of the import deflator to the export deflator. Terms of trade data are taken from the OECD Main Economic Indicators. All series are detrended using the Hodrick–Prescott filter.

a. Terms of trade data available through 1987.

b. Savings for France is measured as GDP less aggregate consumption as annual GNP data were not reported by the IFS.

Table 5: Correlations of Output, Consumption and the Trade Balance with the Real Exchange Rate 1970–1987

A. Output

GDP	CAN	FRA	ITA	GBR	USA
CAN	–	.584	.256	–.112	–.445
FRA	–.687	–	–.548	–.530	–.769
ITA	–.431	.348	–	–.340	–.571
GBR	.528	.677	.643	–	.457
USA	.256	.480	.448	.018	–

B. Consumption

Cons	CAN	FRA	ITA	GBR	USA
CAN	–	.551	.210	.037	–.555
FRA	–.533	–	–.746	–.317	–.616
ITA	–.236	.112	–	–.426	–.116
GBR	.726	.671	.683	–	.582
USA	.357	.380	.415	.076	–

C. Trade Balance

TB	CAN	FRA	ITA	GBR	USA
CAN	–	–.551	–.388	.212	.487
FRA	–.030	–	.280	.078	.009
ITA	–.146	.051	–	.062	.087
GBR	–.338	–.186	–.189	–	–.123
USA	.061	.332	.165	–.236	–

Source: IFS Annual Data, 1970–1988. Output, consumption and the real exchange rate are Hodrick–Prescott filtered. The trade balance is measured as exports less imports, where both series are Hodrick–Prescott filtered. The real exchange rate is defined as the ratio of the domestic CPI to the exchange rate–adjusted foreign CPI.

Table 6: Standard Deviations of International Variables

Country	Time Period	TOT	CPI	TB	CA
CANADA					
	60–88	3.27	5.05	4.71	4.54
	70–88	3.94	5.59	5.41	4.86
FRANCE					
	60–88	4.87	5.77	4.64	3.55
	70–88	5.83	6.43	4.31	3.93
ITALY					
	61–87	5.80	9.43	8.86	10.17
	70–87	6.91	10.21	8.44	9.35
UNITED KINGDOM					
	60–88	4.48	9.36	5.86	6.85
	70–88	5.43	10.49	6.96	8.19
UNITED STATES					
	60–88	5.36	5.21	6.95	3.49
	70–88	6.19	5.60	8.02	4.02

Source: Column 1 is taken from the OECD Main Economic Indicators. Columns 2 through are taken from IFS. All data are detrended using the Hodrick–Prescott filter.

Table 7: Shares of GDP by Sector, 1984.

	CAN	FRA	GER	ITA	JAPAN	U.K.	U.S.
Agriculture	.03	.04	.02	.05	.03	.02	.02
Manufacturing	.19	.25	.33	.27	.29	.23	.21
Mining	.06	n.a.	.01	n.a.	.0	.08	.03
Retail[a]	.13	.14	.11	.15	.14	.12	.17
Transportation[b]	.07	.05	.06	.07	.06	.07	.06
Traded	.50	.48	.53	.54	.53	.52	.50
Electricity, Gas and Water	.03	.05	.03	.05	.03	.03	.03
Construction	.06	.06	.06	.08	.07	.06	.05
Finance, Insurance and Real Estate	.19	.19	.13	n.a.	.15	.19	.22
Private Services[c]	.05	.09	.13	.19	.13	.05	.09
Gov't. Services	.16	.13	.12	.14	.08	.15	.12
Nontraded	.50	.52	.47	.46	.47	.48	.50

Source: OECD International Sectoral Data Base.

a. Includes wholesale and retail trade, restaurants and hotels.
b. Includes transport, storage and communication.
c. Includes community, social and personal services.

Table 8: Volatility of Macroeconomic Variables

A. Standard Deviations of Annual time-series (1970–1986)

	Output	Solow Residuals	Capital	Labor	Investment
CANADA					
Agg	3.35	3.15	3.36	2.57	7.29
T	5.00	3.92	2.55	3.32	9.74
NT	2.73	2.29	3.72	2.14	5.98
GERMANY					
Agg	1.95	1.50	2.79	1.60	5.25
T	2.24	1.64	2.79	1.77	6.51
NT	1.93	1.73	3.15	1.52	5.59
ITALY					
Agg	2.37	2.60	2.58	1.01	5.28
T	3.03	2.69	2.01	1.73	6.18
NT	1.55	2.90	3.82	.66	6.19
JAPAN					
Agg	2.29	2.07	3.27	.90	3.67
T	3.00	2.70	3.40	1.30	5.08
NT	2.40	2.05	3.42	1.20	5.95
U.S.					
Agg	2.69	1.60	2.82	1.96	6.18
T	3.99	2.74	1.76	2.72	7.59
NT	1.47	1.94	4.07	1.26	8.83
5 COUNTRY AVERAGE					
Agg	2.53	2.18	2.96	1.61	5.53
T	3.45	2.74	2.50	2.17	7.02
NT	2.02	2.18	3.64	1.36	6.26

B. Ratio of S.D. of variables to the S.D. of output

	Solow Residuals	Capital	Labor	Investment
CANADA				
Agg	.94	1.00	.77	2.18
T	.78	.51	.66	1.95
NT	.84	1.36	.78	2.19
GERMANY				
Agg	.77	1.43	.82	2.69
T	.73	1.25	.79	2.91
NT	.90	1.63	.79	2.90
ITALY				
Agg	1.09	1.09	.43	2.23
T	.89	.66	.57	2.04
NT	1.87	2.46	.43	3.99
JAPAN				
Agg	.90	1.43	.39	1.60
T	.90	1.13	.43	1.69
NT	.85	1.43	.50	2.98
U.S.				
Agg	.59	1.05	.73	2.30
T	.69	.44	.68	1.90
NT	1.32	2.77	.86	5.16

Source: OECD International Sectoral Data Base. Data are detrended using the Hodrick–Prescott filter. Standard deviations are calculated over the period from 1970 to the last available observation.

a. The Solow residuals are estimated from capital, labor and output data which are detrended using the Hodrick–Prescott filter.

Table 9: **Shares of Nontraded Goods in Consumption**

A. Services as a share of Private Final Consumption

	60:1–69:4	70:1–79:4	80:1–88:4
CANADA	.379	.415	.455
FRANCE	.379	n.a.	.386
ITALY	n.a.	n.a.	.328
JAPAN[a]	n.a.	.450[b]	.497
UNITED KINGDOM	.294	.334	.398
UNITED STATES	.421	.455	.508
UNITED STATES[c]	n.a.	.523	.558

B. Expenditure on Nontradables[d] as a share of Private Final Consumption:

	60:1–69:4	70:1–79:4	80:1–88:4
CANADA	n.a.	n.a.	n.a.
FRANCE	.225[e]	n.a.	.350
ITALY	n.a.	n.a.	.271
JAPAN	n.a.	.249	.280
UNITED KINGDOM	.189	.223	.259
UNITED STATES[f]	.363	.392	.443

Source: OECD Quarterly Accounts

a. Private final consumption includes net direct purchases abroad and gifts.
b. Average for the period 1975:1–1979:4.
c. Data from Citibase; expenditure on services (private plus government) as a share of total consumption.
d. Expenditure on "Rent, Fuel, and Power" and "Transportation and Communication" used as proxies for expenditure on nontradables.
e. Average for the period 1966:1–1974:4.
f. Based on Citibase data. Calculated as the share of clothing and shoe repair, personal care (barbershops, etc.), housing, household utilities, medical care, personal business, auto repair, local and intercity public transportation, and education expenditures in total personal consumption expenditures.

Table 10: Standard Deviations of Consumption

Country	Time Period	Aggregate	Private Final Consumption	Traded	Nontraded
CANADA	60–88	2.34	2.07	4.10	2.88
	70–88	2.71	1.83	4.97	3.38
FRANCE	60–88	1.62	n.a.	n.a.	1.81
	70–88	1.59	1.47	2.12	1.89
ITALY	60–87	2.13	n.a.	n.a.	n.a.
	81–87	1.20	1.38	1.64	0.87
JAPAN	61–88	2.74	n.a.	n.a.	3.06
	71–87	2.91	1.94	3.07	3.27
GREAT BRITAIN	60–88	2.05	n.a.	n.a.	2.71
	70–88	2.48	3.72	3.35	3.31
UNITED STATES	60–88	2.24	1.16	2.80	1.91
	70–88	1.95	1.21	3.10	2.06

Source: OECD Quarterly Accounts. U.S. data from Citibase. Data are converted from quarterly to annual time–series by taking annual averages. The annual data are detrended by using the Hodrick–Prescott filter.

Table 11: Long–run Shares of Investment, Consumption and Trade in GDP

	I/GDP	C/GDP	Trade/GDP
CANADA			
60–88	.229	.763	.227
70–88	.226	.763	.245
FRANCE			
60–88	.237	.759	.176
70–88	.232	.766	.203
ITALY			
60–88	.244	.786	.183
70–88	.245	.757	.202
UNITED KINGDOM			
60–88	.187	.817	.239
70–88	.185	.817	.260
UNITED STATES			
60–88	.190	.817	.071
70–88	.189	.823	.084
Five Country Avg			
60–88	.217	.788	.179
70–88	.215	.785	.209
Model			
$\Theta = \Theta^* = 0.5$	.263	.737	.188
$\Theta = .2,\ \Theta^* = .8$	.263	.737	.075
$\Theta = .8,\ \Theta^* = .2$	.263	.737	.301

Source: IFS Annual data. Trade (in column 3) is defined as the average of nominla exports plus nominal imports.

Table 12: **Correlations Between Prices and Quantities**

	(C_T, C_{NT})	(Y_T, Y_{NT})	$(\frac{P_N}{P_T}, \frac{C_N}{C_T})$	$(\frac{P_N}{P_T}, \frac{Y_N}{Y_T})$
CANADA[a]				
60–88	.462	.176	–.504	.378
70–88	.620	.620	–.585	.440
FRANCE[b]				
70–88	.832	.833	–.484	.197
GERMANY[c]				
70–88	n.a.	.609	n.a.	.498
ITALY[c]				
60–87	n.a.	.863	n.a.	.069
70–87	n.a.	.862	n.a.	.040
80–87	.864	–	–.650	–
JAPAN[a]				
70–87	.909	.492	.034	.032
UNITED KINGDOM[a]				
62–88	.739	n.a.	–.348	n.a.
70–88	.773	.914	–.302	.199
UNITED STATES[a]				
60–88	.759	1.0	–.685	.488
70–88	.724	1.0	–.739	.537

Source: Columns 1 and 2 from OECD Quarterly Accounts. Columns 2 and 4 are from the OECD Intersectoral Data Base. All series are detrended using the Hodrick–Prescott filter.

a. Output data available through 1986.
b. Output data available through 1984.
c. Output data available through 1985.

Table 13: Parameter Values

Technology	
$\gamma = 2.73$	Rate of technical progress (percent per annum)
$\delta = .10$	Depreciation rate
$s^T (= s^{NT}) = 0.5$	Share of production of traded (and non-traded) goods in total output
$\alpha^T = 0.61$	Labor share in traded-good industry
$\alpha^{NT} = 0.56$	Labor share in nontraded-good industry
$\nu^T = 0.521$	Share of work effort allocated to traded-good production
$\nu^{NT} = 0.479$	Share of work effort allocated to nontraded-good production
$1/a = -3.173$	Intertemporal elasticity of substitution in leisure
Preferences	
$\Phi = 0.5$	Home country's share of world wealth
$\beta = 0.96$	Rate of time preference
$1/\sigma = 0.5$	Intertemporal elasticity of substitution
$1/1+\mu = 0.44$	Elasticity of substitution between traded and nontraded goods
$\theta = 0.5$	Share of domestically-produced goods in consumer's bundle of traded goods.

TABLE 14: SIMULATION RESULTS

Standard Deviations:

Variable	Data:		Case 1 Model:	Case 2 Model:	Case 3 Model:	Case 4 Model:
Aggregate:						
Output:	2.53	(2.00, 3.06)	2.58	2.60	2.70	2.60
Capital:	2.96	(2.62, 3.30)	2.73	2.99	3.09	2.88
Labor:	1.61	(0.92, 2.30)	1.90	2.28	2.47	1.99
Investment:	5.53	(4.20, 6.86)	5.84	5.85	5.88	6.01
Consumption:	2.03	(1.04, 3.02)	1.54	1.81	1.86	1.69
Traded Good Sector:						
Output:	3.45	(2.38, 4.52)	3.21	3.37	3.62	3.24
Capital:	2.50	(1.85, 3.15)	2.57	2.57	3.06	2.62
Labor:	2.17	(1.34, 3.00)	1.78	2.41	2.46	1.86
Investment:	7.02	(5.26, 8.78)	9.22	9.22	9.37	9.28
Consumption:	3.32	(2.29, 4.35)	1.08	3.17	2.96	1.12
Nontraded Good Sector:						
Output:	2.02	(1.48, 2.56)	2.86	2.89	2.87	2.91
Capital:	3.64	(3.28, 4.00)	2.97	3.03	2.97	3.10
Labor:	1.36	(0.82, 1.90)	1.12	1.20	1.13	1.59
Investment:	6.51	(5.20, 7.82)	6.13	6.19	6.13	6.41
Consumption:	2.78	(2.04, 3.52)	1.86	1.89	1.87	2.35
Domestic Correlations:						
Corr(C,Y):	0.88*	(0.82, 0.95)	0.92	0.89	0.91	0.86
Corr(I,Y):	0.87	(0.83, 0.90)	0.95	0.92	0.93	0.91
Corr(CT,CNT):	0.77*	(0.66, 0.88)	0.83	0.38	0.39	0.64
Corr(YT,YNT):	0.70	(0.41, 1.00)	0.45	0.38	0.37	0.42
Corr(APL,Y):	0.76	(0.63, 0.90)	0.69	0.54	0.45	0.72
Corr(N,Y):	0.69	(0.55, 0.83)	0.85	0.77	0.81	0.80
Domestic Price–Quantity Correlations:						
Corr(PN/PT,CN/CT):	−0.42*	(−.71, −.12)	−1.00	−0.45	−0.54	−0.30
Corr(PN/PT,YN/YT):	0.28	(.07, .49)	−0.70	−0.52	−0.61	−0.56
International Variables:						
Correlations:						
Corr(Y,Y*)	0.64	(0.49, 0.78)	0.64	0.53	0.52	0.63
Corr(C,C*)	0.50	(0.25, 0.75)	0.78	0.39	0.42	0.63
Corr(S,I)	0.74*	(0.54, 0.95)	0.89	0.77	0.75	0.89
Corr(TB,Y)	−0.47*	(−.67, −.28)	−0.42	−0.47	−0.48	−0.42
Corr(CA,Y)	−0.58*	(−.67, −.49)	−0.30	−0.38	−0.40	−0.29
Standard Deviations:						
s.d.(TOT)	5.66	(4.56, 6.76)	2.05	2.56	2.26	2.13
s.d.(TB)	6.63	(4.88, 8.38)	0.45	0.57	0.61	.46
s.d.(CA)	6.07	(3.55, 8.59)	2.61	3.88	4.06	2.62

TABLE 14: SIMULATION RESULTS (cont):

Standard Deviations:

Variable	Data:		Case 1 Model:	Case 5 Model:	Case 6 Model:	Case 7 Model:
Aggregate:						
Output:	2.53	(2.00, 3.06)	2.58	2.62	2.61	2.65
Capital:	2.96	(2.62, 3.30)	2.73	3.13	3.29	2.97
Labor:	1.61	(0.92, 2.30)	1.90	2.35	2.49	2.29
Investment:	5.53	(4.20, 6.86)	5.84	6.03	6.06	5.87
Consumption:	2.03	(1.04, 3.02)	1.54	1.94	2.05	1.73
Traded Good Sector:						
Output:	3.45	(2.38, 4.52)	3.21	3.40	3.33	3.31
Capital:	2.50	(1.85, 3.15)	2.57	2.62	2.62	2.68
Labor:	2.17	(1.34, 3.00)	1.78	2.47	2.31	1.96
Investment:	7.02	(5.26, 8.78)	9.22	9.27	9.26	9.25
Consumption:	3.32	(2.29, 4.35)	1.08	3.18	3.30	1.70
Nontraded Good Sector:						
Output:	2.02	(1.48, 2.56)	2.86	2.94	2.94	3.14
Capital:	3.64	(3.28, 4.00)	2.97	3.16	3.24	3.21
Labor:	1.36	(0.82, 1.90)	1.12	1.64	1.52	1.76
Investment:	6.51	(5.20, 7.82)	6.13	6.47	6.57	6.26
Consumption:	2.78	(2.04, 3.52)	1.86	2.37	2.37	2.28
Domestic Correlations:						
Corr(C,Y):	0.88*	(0.82, 0.95)	0.92	0.85	0.84	0.91
Corr(I,Y):	0.87	(0.83, 0.90)	0.95	0.88	0.86	0.94
Corr(CT,CNT):	0.77*	(0.66, 0.88)	0.83	0.31	0.47	0.54
Corr(YT,YNT):	0.70	(0.41, 1.00)	0.45	0.36	0.39	0.35
Corr(APL,Y):	0.76	(0.63, 0.90)	0.69	0.56	0.45	0.56
Corr(N,Y):	0.69	(0.55, 0.83)	0.85	0.74	0.70	0.81
Domestic Price–Quantity Correlations:						
Corr(PN/PT,CN/CT):	–0.42*	(–.71, –.12)	–1.00	–0.21	–0.43	–0.50
Corr(PN/PT,YN/YT):	0.28	(.07, .49)	–0.70	–0.42	–0.54	–0.60
International Variables:						
Correlations:						
Corr(Y,Y*)	0.64	(0.49, 0.78)	0.64	0.53	0.52	0.56
Corr(C,C*)	0.50	(0.25, 0.75)	0.78	0.33	0.25	0.54
Corr(S,I)	0.74*	(0.54, 0.95)	0.89	0.78	0.79	0.86
Corr(TB,Y)	–0.47*	(–.67, –.28)	–0.42	–0.47	–0.48	–0.46
Corr(CA,Y)	–0.58*	(–.67, –.49)	–0.30	–0.38	–0.39	–0.33
Standard Deviations:						
s.d.(TOT)	5.66	(4.56, 6.76)	2.05	2.62	2.78	2.18
s.d.(TB)	6.63	(4.88, 8.38)	0.45	0.58	0.60	.54
s.d.(CA)	6.07	(3.55, 8.59)	2.61	3.88	3.85	2.96

Table 15: Technology and Taste Shocks used in Simulations

Case 1: Solow Residuals only

Variance–Covariance Matrix of Productivity Shocks:

3.62	1.23	1.21	0.51
1.23	1.99	0.51	0.27
1.21	0.51	3.62	1.23
0.51	0.27	1.23	1.99

Autocorrelation Matrix of Productivity Shocks:

0.154	0.040	−0.199	0.262
−0.015	0.632	−0.110	0.125
−0.199	0.262	0.154	0.040
−0.110	0.125	−0.015	0.632

Case 2: Taste Shocks for Home–Produced Traded Good:

Variance–Covariance Matrix of Preference Shocks:

3.60	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

Autocorrelation Matrix of Preference Shocks:

0.900	0.000	0.000
0.000	0.900	0.000
0.000	0.000	0.900

Case 3: Small Taste Shocks for Home–Produced Traded Good:

Variance–Covariance Matrix of Preference Shocks:

0.036	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000

Autocorrelation Matrix of Preference Shocks:

0.999	0.000	0.000
0.000	0.999	0.000
0.000	0.000	0.999

Case 4: Taste Shocks for Nontraded Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 2.000 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.632 & 0.000 & 0.000 \\ 0.000 & 0.632 & 0.000 \\ 0.000 & 0.000 & 0.632 \end{vmatrix}$$

Case 5: Taste Shocks to Home–Produced Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 3.600 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 2.000 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.900 & 0.000 & 0.000 \\ 0.000 & 0.900 & 0.000 \\ 0.000 & 0.000 & 0.630 \end{vmatrix}$$

Case 6: Taste Shock to Home–Produced Goods, Correlated across goods

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 3.600 & 0.000 & 1.340 \\ 0.000 & 0.000 & 0.000 \\ 1.340 & 0.000 & 3.600 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.900 & 0.000 & 0.000 \\ 0.000 & 0.900 & 0.000 \\ 0.000 & 0.000 & 0.630 \end{vmatrix}$$

Case 7: Small Taste Shocks to Home–Produced Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 0.036 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.020 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.995 & 0.000 & 0.000 \\ 0.000 & 0.995 & 0.000 \\ 0.000 & 0.000 & 0.995 \end{vmatrix}$$

Figure 3a: Home Country Response to Traded–Good Productivity Shock (A^T)

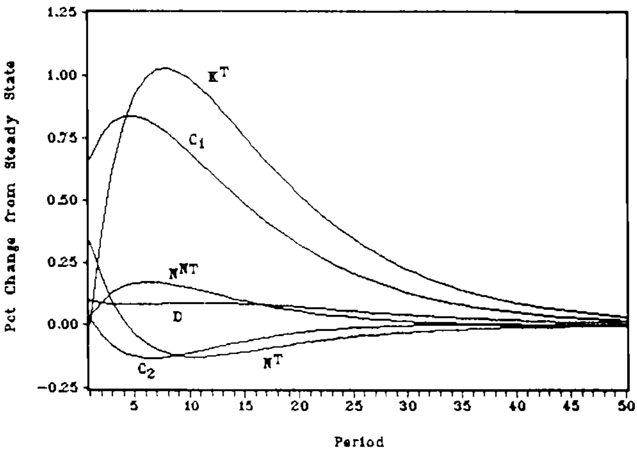


Figure 3b: Foreign Country Response to Traded–Good Productivity Shock (A^T)

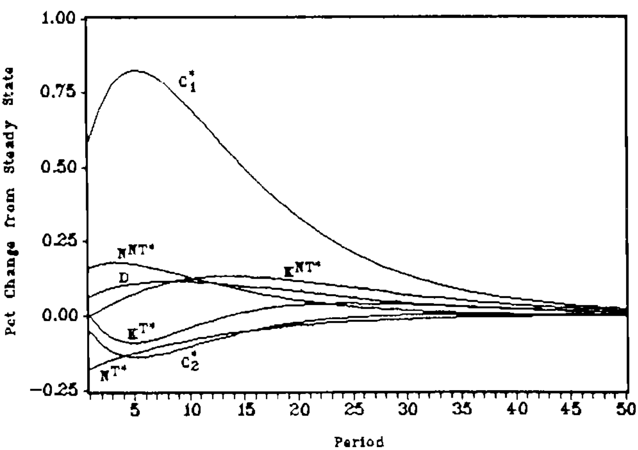


Figure 4a: Home Country Response to Nontraded–Good Productivity Shock (A^{NT})

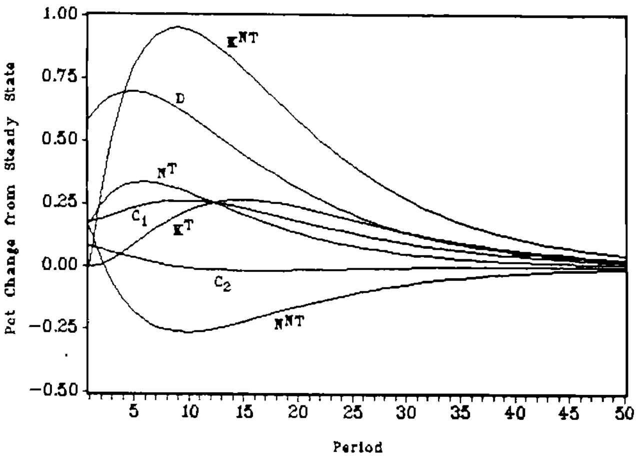


Figure 1b: Foreign Country Response to Traded–Good Productivity Shock (A^{NT})

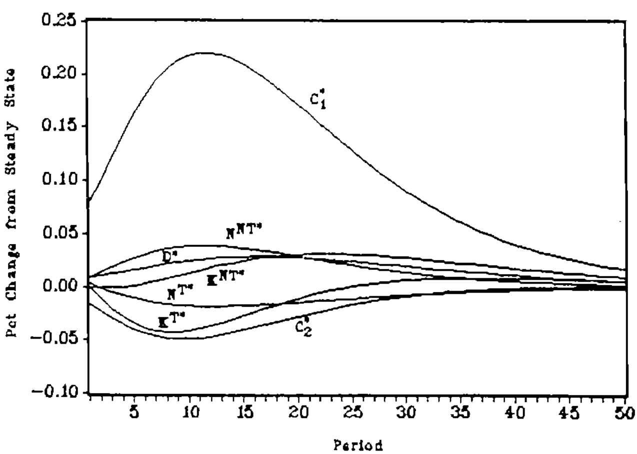


Figure 5a: Home Country Response to Traded–Good Taste Shock (τ_1)

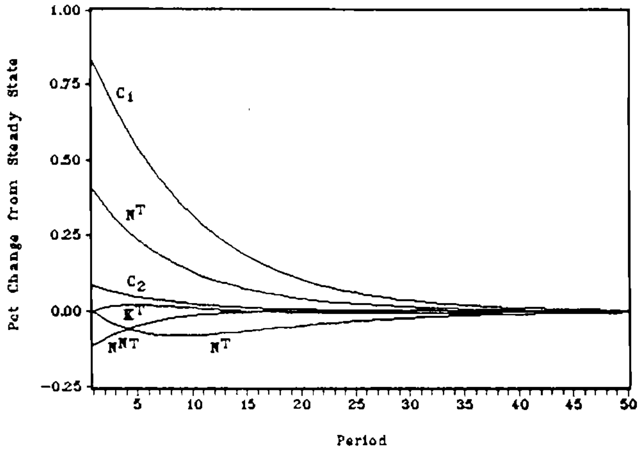


Figure 5b: Foreign Country Response to Traded–Good Taste Shock (τ_1)

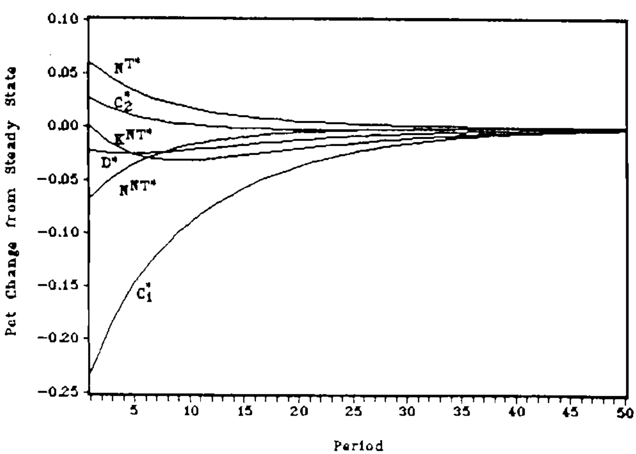


Figure 6a: Home Country Response to Nontraded–Good Taste Shock (τ_3)

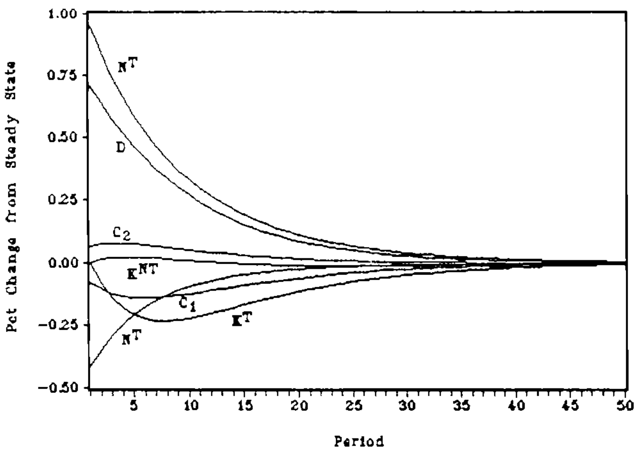
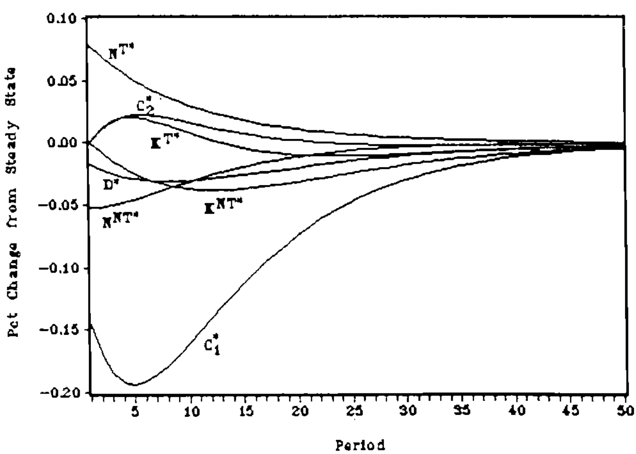


Figure 6b: Foreign Country Response to Nontraded–Good Taste Shock (τ_3)



APPENDIX A: **Description of the Data Sources**

The International Sectoral Data Base (ISDB) compiled by the OECD provides time series data on output, employment, investment, capital stocks and factor payments by sectors in thirteen OECD countries. The sector classification is based on the ISIC. Gross capital stocks are estimated from investment data allowing for varying rates of depreciation across countries and across sectors. For a detailed discussion of the estimation procedure, see Meyer–zu–Schloctern (1988), pp. 2–6. We construct time series for productivity growth in the traded– and nontraded–goods–producing sectors from constant–price, domestic–currency series of output, capital, compensation of employees and the total number of employees.

We take consumption data from the OECD Quarterly National Accounts. We decompose private final consumption of commodities by type (durables, semi–durables, non–durables and services) and by object (food, beverages and tobacco; clothing and footwear; gross rent, fuel and power; transport and communication; furniture and household operations; and other goods and services). We use two proxies for consumption of nontradables: services from the classification by type and gross rent, fuel and power plus transport and communication from the classification by object. U.S. data for these categories are taken from the CITIBASE database. We construct the relative prices of nontradables in each of the countries from the price deflators of the service and non–service components of consumption. Deseasonalized quarterly data from the OECD are annualized by averaging.

We take data on aggregate output, investment, savings, net foreign investment, exports and imports from the International Financial Statistics of the IMF. We deflate production data using the GNP (GDP) deflator and consumption data using the CPI. In some cases, data for the United States are taken from CITIBASE. The export– and import–price deflators used to calculate the terms of trade are taken from the OECD Main

Economics Indicators.

Unless otherwise noted, empirical results cited in the body of the paper are based on data detrended using the Hodrick–Prescott filter. Results based on data detrended by taking first differences (growth rates) appear in Appendix B.

APPENDIX B

Table B1: Cross–Country Correlations of Output and Productivity

A. Correlations of Output (1971–1988)

	CANADA	JAPAN	GERMANY	ITALY
USA				
Agg	.693	.623	.821	.494
T	.746	.557	.811	.422
NT	−.027	.317	.601	.604
CANADA				
Agg		.518	.705	.603
T		.562	.698	.578
NT		.346	.249	.186
JAPAN				
Agg			.697	.445
T			.682	.673
NT			.642	.091
GERMANY				
Agg				.813
T				.823
NT				.682

B. Correlations of Solow Residuals (1971–1984)

	CANADA	JAPAN	GERMANY	ITALY
USA				
Agg	.659	.486	.575	.151
T	.674	.370	.381	−.070
NT	.148	−.214	.135	.553
CANADA				
Agg		.303	.518	.225
T		.317	.449	.306
NT		.175	.470	.288
JAPAN				
Agg			.540	.011
T			.579	.412
NT			.469	−.456
GERMANY				
Agg				.599
T				.627
NT				.134

Source: Output and Solow residuals from OECD International Sectoral Data Base. All data are logged and first–differenced.

Table B2: Cross–Country Correlations in Consumption

A. Correlations of Aggregate Consumption (1970–1988).

	CANADA	FRANCE	ITALY	U.K.
USA	.278	.205	–.432	.321
CANADA		.451	.052	.086
FRANCE			–.007	.112
ITALY				.032

B. Correlations of Aggregate, Private Final Consumption, and Consumption of Traded and Nontraded Goods (1971–1988).

	CANADA	FRANCE	JAPAN	U.K.
USA				
	.250	.017	.269	.472
	.442	.285	.494	.554
	.335	.278	.477	.589
	.501	.280	.436	.322
CANADA				
		.515	.445	.261
		.536	.412	.268
		.397	.426	.376
		.489	.161	.100
FRANCE				
			.783	.352
			.733	.261
			.668	.466
			.539	–.190
JAPAN				
				.656
				.587
				.645
				.221

Source: Part A is based on IFS annual data. Part B is based on data from the OECD Quarterly Accounts which are annualized by averaging. All data are first–differenced.

Table B3: Correlations between Savings, Investment, Trade Balance, Current Account and Output

	$Corr(\hat{S},\hat{I})$	$Corr(\hat{TB},\hat{Y})$	$Corr(\hat{CA},\hat{Y})$	$Corr(TOT^a,Y)$	$Corr(TOT^a,TB)$
CANADA					
60–88	.846	–.339	–.157	–.422	.001
70–88	.861	–.365	–.178	–.517	–.052
FRANCE[b]					
60–88	.799	–.170	–.139	–.357	–.419
70–88	.753	.061	.008	–.359	–.546
ITALY					
61–87	.644	–.261	–.664	.256	–.212
70–87	.642	–.214	–.722	.293	–.258
UNITED KINGDOM					
60–88	.733	–.376	–.301	–.119	–.593
70–88	.724	–.359	–.244	–.145	–.699
UNITED STATES					
60–88	.932	–.356	–.390	–.413	.084
70–88	.933	–.376	–.433	–.392	.062

Source: Columns 1, 2 and 3 from IFS annual data. The terms of trade are defined as the ratio of the import deflator to the export deflator. Terms of trade data are taken from the OECD Main Economic Indicators. All series are first–differenced.

a. Terms of trade data available through 1987.

b. Savings for France is measured as GDP less aggregate consumption as annual GNP data were not reported by the IFS.

Table B4: Correlations of Output, Consumption and the Trade Balance with the Real Exchange Rate, 1970–1987

A. Output

GDP	CAN	FRA	ITA	GBR	USA
CAN	–	.111	–.103	–.079	–.234
FRA	–.386	–	–.200	–.338	–.476
ITA	.030	.051	–	–.120	–.037
GBR	.449	.560	.485	–	.419
USA	.053	.203	.114	.057	–

B. Consumption

Cons	CAN	FRA	ITA	GBR	USA
CAN	–	.193	–.044	.083	–.334
FRA	–.254	–	–.400	–.154	–.354
ITA	–.187	.110	–	–.359	–.171
GBR	.687	.696	.661	–	.621
USA	.170	.250	.217	.098	–

C. Trade Balance

TB	CAN	FRA	ITA	GBR	USA
CAN	–	–.325	–.266	.146	.035
FRA	–.290	–	.142	–.091	–.191
ITA	–.081	–.047	–	.043	–.048
GBR	–.328	–.180	–.189	–	–.198
USA	–.121	.418	.255	–.312	–

Source: IFS Annual Data, 1970–1988. Output, consumption and the real exchange rate are first–differenced. The trade balance is measured as exports less imports, where both series are first–differenced. The real exchange rate is defined as the ratio of the domestic CPI to the exchange rate–adjusted foreign CPI.

Table B5: Standard Deviations of International Variables

Country	Time Period	TOT	CPI	TB	CA
CANADA					
	60–88	3.19	3.20	4.84	5.20
	70–88	3.81	2.86	5.24	5.27
FRANCE					
	60–88	4.46	3.41	5.69	4.33
	70–88	5.37	3.30	6.02	5.06
ITALY					
	60–88	4.90	5.81	12.49	8.39
	70–88	5.89	5.20	12.88	8.98
UNITED KINGDOM					
	60–88	3.74	5.09	5.51	6.35
	70–88	4.53	5.11	5.91	6.82
UNITED STATES					
	60–88	4.97	3.18	8.12	3.39
	70–88	5.70	3.02	8.54	3.96

Source: Column 1 is taken from the OECD Main Economic Indicators. Columns 2 through are taken from IFS. All data are detrended by first–differencing.

Table B6: Volatility of Macroeconomic Variables

A. Standard Deviations of Annual time-series (1970–1986)

	Output	Solow Residuals	Capital	Labor	Investment
CANADA					
Agg	3.00	3.25	4.18	2.22	6.55
T	5.07	4.15	2.52	3.12	9.46
NT	2.06	2.36	5.44	1.90	4.92
GERMANY					
Agg	2.02	1.69	1.84	1.46	4.86
T	2.59	2.14	2.05	1.69	5.88
NT	1.68	1.53	2.06	1.36	5.46
ITALY					
Agg	2.68	2.91	2.24	.78	6.45
T	3.58	3.51	2.19	1.31	7.70
NT	1.48	2.42	3.25	.52	5.80
JAPAN					
Agg	2.40	2.07	2.09	0.91	3.76
T	3.36	2.98	2.29	1.24	4.58
NT	2.63	2.23	2.11	1.21	6.75
U.S.					
Agg	2.87	1.50	2.16	2.10	6.90
T	4.34	2.87	2.06	2.97	8.00
NT	1.48	1.26	2.97	1.29	7.73
5 COUNTRY AVERAGE					
Agg	2.59	2.28	2.50	1.49	5.70
T	3.79	3.13	2.22	2.07	7.13
NT	1.87	1.96	3.17	1.26	6.13

B. Ratio of S.D. of variables to the S.D. of output

	Solow Residuals	Capital	Labor	Investment
CANADA				
Agg	1.08	1.39	.74	2.18
T	.82	.48	.62	1.87
NT	1.15	2.64	.92	2.39
GERMANY				
Agg	.83	.91	.72	2.41
T	.83	.79	.65	2.27
NT	.91	1.23	.81	3.25
ITALY				
Agg	1.09	.84	.29	2.41
T	.98	.61	.37	2.15
NT	1.64	2.20	.35	3.92
JAPAN				
Agg	.86	.87	.38	1.57
T	.89	.68	.37	1.36
NT	.85	.80	.46	2.57
U.S.				
Agg	.52	.75	.73	2.40
T	.66	.47	.68	1.84
NT	.85	2.01	.87	5.22

Source: OECD International Sectoral Data Base. Data are detrended by taking first-differences. Standard deviations are calculated over the period from 1970 to the last available observation.

a. The Solow residuals are estimated from first-differenced capital, labor and output data.

Table B7: **Standard Deviations of Consumption**

Country	Time Period	Aggregate	Private Final Consumption	Traded	Nontraded
CANADA	61–88	1.64	2.08	2.85	1.79
	70–88	1.81	2.34	3.37	1.42
FRANCE	61–88	1.67	1.78	n.a.	n.a.
	70–88	1.35	1.55	1.85	1.37
ITALY	61–87	2.07	n.a.	n.a.	n.a.
	81–87	1.32	1.57	1.10	0.92
JAPAN	61–88	2.78	3.05	n.a.	n.a.
	71–87	2.26	2.45	3.10	1.91
UNITED KINGDOM	61–88	1.81	2.24	n.a.	n.a.
	70–88	2.09	2.63	2.96	2.76
UNITED STATES	61–88	1.57	1.66	2.54	1.00
	70–88	1.53	1.77	2.78	0.94

Source: OECD Quarterly Accounts. U.S. data from Citibase. Data are converted from quarterly to annual time–series by taking annual averages. The annual data are detrended by taking first–differences.

Table B8: Correlations Between Prices and Quantities

	(C_T, C_{NT})	(Y_T, Y_{NT})	$(\frac{P_N}{P_T}, \frac{C_N}{C_T})$	$(\frac{P_N}{P_T}, \frac{Y_N}{Y_T})$
CANADA[a]				
61–88	.433	.356	–.295	–.192
70–88	.622	.305	–.270	–.154
FRANCE[b]				
67–88	.640	n.a.	–.587	n.a.
70–88	.681	.653	–.598	–.186
GERMANY[c]				
61–85	n.a.	.679	n.a.	–.532
70–85	n.a.	.687	n.a.	.024
ITALY[c]				
60–87	n.a.	.851	n.a.	.117
70–87	n.a.	.856	n.a.	.263
80–87	.999	–	–.550	–
JAPAN[a]				
70–87	.822	.370	.251	.084
UNITED KINGDOM[a]				
63–88	.565	n.a.	–.187	n.a.
70–88	.972	.757	–.084	–.078
UNITED STATES[a]				
61–88	.628	830	–.594	–.332
70–88	.647	874	–.700	–.373

Source: Columns 1 and 2 from OECD Quarterly Accounts. Columns 2 and 4 are from the OECD Intersectoral Data Base. All series are detrended using the Hodrick–Prescott filter.

a. Output data available through 1986.
b. Output data available through 1984.
c. Output data available through 1985.

Table B9: Domestic Correlations

	Hodrick–Prescott Filter		First–differenced Data	
	(C, Y)	(I, Y)	(C, Y)	(I, Y)
CANADA				
60–88	.889	.896	.829	.859
70–88	.930	.927	.838	.882
FRANCE				
60–88	.808	.856	.835	.771
70–88	.801	.842	.793	.710
ITALY				
60–87	.320	.895	.451	.778
70–87	.371	.879	.401	.817
GREAT BRITAIN				
60–88	.846	.842	.803	.726
70–88	.866	.835	.830	.689
UNITED STATES				
60–88	.941	.845	.907	.866
70–88	.935	.849	.899	.884

Source: IFS Annual data.

Table B10: Correlation between (P/P^*) and (Y_T/Y_T^*) (1970–85)

A. Hodrick–Prescott Filtered Data

	CAN	GER	ITA	JPN	USA
CAN	–	.112	–.305	–.090	.689
GER	–.250	–	.720	.171	–.636
ITA	–.069	–.738	–	–.476	–.518
JPN	–.192	.088	.537	–	–.476
USA	.384	.800	.893	.476	–

B. First–differenced data

	CAN	GER	ITA	JPN	USA
CAN	–	.104	–.322	.012	.681
GER	–.070	–	.693	–.032	–.401
ITA	–.216	–.746	–	–.645	–.535
JPN	–.181	.007	.556	–	–.561
USA	.223	.383	.598	.343	–

APPENDIX C: The Social Planner's Problem

This appendix contains a full description of the social planner's problem and the first–order conditions as they appear after linearization around the steady–state equilibrium. The social planner maximizes:

$$\max \beta^t E_t \sum_{t=0}^{\infty} [\omega\, u(c_{1t}, c_{2t}, d_t, L_t) + (1-\omega) u(c_{1t}^*, c_{2t}^*, d_t^*, L_t^*)] \tag{C.1}$$

over

$$(c_{1t}, c_{2t}, d_t, L_t, N_t^T, N_t^{NT}, I_t^T, I_t^{NT}, K_{t+1}^T, K_{t+1}^{NT})$$

in the home country and over

$$(c_{1t}^*, c_{2t}^*, d_t^*, L_t^*, N_t^{T*}, N_t^{NT*}, I_t^{T*}, I_t^{NT*})$$

in the foreign country subject to the market clearing conditions for each of the four goods:

$$Y_t^T = c_{1t} + c_{1t}^* + I_t^T \tag{C.2}$$

$$Y_t^{T*} = c_{2t} + c_{2t}^* + I_t^{T*} \tag{C.3}$$

$$Y_t^{NT} = d_t + I_t^{NT} \tag{C.4}$$

$$Y_t^{NT*} = d_t^* + I_t^{NT*}, \tag{C.5}$$

the four equations describing the evolution of the capital stocks:

$$I_t^T = \gamma K_{t+1}^T - (1-\delta)\, K_t^T \tag{C.6}$$

$$I_t^{NT} = \gamma K_{t+1}^{NT} - (1-\delta)\, K_t^{NT} \tag{C.7}$$

$$I_t^{T*} = \gamma K_{t+1}^{T*} - (1-\delta)\, K_t^{T*} \tag{C.8}$$

$$I_t^{NT*} = \gamma K_{t+1}^{NT*} - (1-\delta)\, K_t^{NT*}, \tag{C.9}$$

where future capital stocks are augmented by the rate of technical progress, and the labor constraints in each country:

$$N_t^T + N_t^{NT} + L_t = 1 \tag{C.10}$$

$$N_t^{T*} + N_t^{NT*} + L_t^* = 1. \tag{C.11}$$

Equations (C.12) through (C.26) are the home–country's first–order conditions for this maximization problem in linearized form. Maximizing with respect to the consumption goods and leisure in the home country we find:

$$\epsilon_{11}\hat{c}_{1t} + \epsilon_{12}\hat{c}_{2t} + \epsilon_{13}\hat{d}_t + \epsilon_{14}\hat{L}_t = \hat{p}_t^T \tag{C.12}$$

$$\epsilon_{21}\hat{c}_{1t} + \epsilon_{22}\hat{c}_{2t} + \epsilon_{23}\hat{d}_t + \epsilon_{24}\hat{L}_t = \hat{p}_t^{T*} \tag{C.13}$$

$$\epsilon_{31}\hat{c}_{1t} + \epsilon_{32}\hat{c}_{2t} + \epsilon_{33}\hat{d}_t + \epsilon_{34}\hat{L}_t = \hat{p}_t^{NT} \tag{C.14}$$

$$\epsilon_{41}\hat{c}_{1t} + \epsilon_{42}\hat{c}_{2t} + \epsilon_{43}\hat{d}_t + \epsilon_{44}\hat{L}_t = \hat{w}_t \tag{C.15}$$

where

$$\epsilon_{ij} = \frac{u_{ij}(-)c_j}{u_i(-)}.$$

The first–order conditions for work effort in the two industries are:

$$\hat{p}_t^T + \hat{A}_t^T + \eta_{KN}^T \hat{K}_t^T + \eta_{NN}^T \hat{N}_t^T = \hat{w}_t \tag{C.16}$$

$$\hat{p}_t^{NT} + \hat{A}_t^{NT} + \eta_{KN}^{NT} \hat{K}_t^{NT} + \eta_{NN}^{NT} \hat{N}_t^{NT} = \hat{w}_t \tag{C.17}$$

where eta_{ij} is the elasticity of the marginal product of factor i with respect to factor j. Totally differentiation of the labor constraint yields:

$$\frac{(1-N)}{N}\hat{L}_t + \nu^T \hat{N}_t^T + \nu^{NT} \hat{N}_t^N = 0\,. \tag{C.18}$$

where N is the (constant) fraction of time allocated to work effort and v^i is the (constant) fraction of time allocated to sector i.

The first–order conditions for choosing next period's capital stocks are:

$$\hat{p}_{t+1}^T + \eta_A^T \hat{A}_{t+1}^T + \eta_{KA}^T \hat{K}_{t+1}^T + \eta_{NA}^T \hat{N}_{t+1}^T = \hat{p}_t^T \tag{C.19}$$

$$\hat{p}_{t+1}^{NT} + \eta_A^{NT} \hat{A}_{t+1}^{NT} + \eta_{KA}^{NT} \hat{K}_{t+1}^{NT} + \eta_{NA}^{NT} \hat{N}_{t+1}^{NT} = \hat{p}_t^N{}_T \tag{C.20}$$

The investment equations and budget constraints in totally differentiated form are:

$$\hat{I}_t^T - \frac{\gamma}{\gamma-(1-\delta)} \hat{K}_{t+1}^T + \frac{(1-\delta)}{\gamma-(1-\delta)} \hat{K}_t^T = 0 \tag{C.21}$$

$$\hat{I}_t^{NT} - \frac{\gamma}{\gamma-(1-\delta)} \hat{K}_{t+1}^{NT} + \frac{(1-\delta)}{\gamma-(1-\delta)} \hat{K}_t^{NT} = 0 \tag{C.22}$$

$$\hat{A}_t^T + s_k^T \hat{K}_t^T + S_N^T \hat{N}_t^T - s_{c1} \hat{c}_{1t} - s_{c1}^* \hat{c}_{1t}^* - s_i^T \hat{I}_t^T = 0 \tag{C.23}$$

$$\hat{A}_t^{NT} + s_k^{NT} \hat{K}_t^{NT} + S_N^{NT} \hat{N}_t^{NT} - s_d \hat{d}_t - s_i^{NT} \hat{I}_t^{NT} = 0 \,. \tag{C.24}$$

The share parameters, s_{c1} and $s_{c1}{}^*$, denote the shares of consumption of good 1 in total output of the home–produced traded good and s_i^T is the share of output of the home traded good allocated to investment. Similary,s_d and s_i^{NT} are the shares of the domestic consumption and investment of the nontraded good in total output of the nontraded good. The parameters s_K and s_N are the capital and labor shares in each industry. Symmetric equations are similarly derived for the foreign country.

APPENDIX D: **Simulation Results based on Growth–Rate Filtered Data**

This appendix contains simulation results based on Solow residuals calculated from growth rate detrended (first–differenced) data. The estimated autocorrelation matrix of the Solow residuals is:

$$\text{(D.1)} \qquad \Omega = \begin{vmatrix} 0.231 & -0.412 & 0.090 & -0.057 \\ -0.117 & 0.324 & -0.081 & 0.150 \\ 0.090 & -0.057 & 0.231 & -0.412 \\ -0.081 & 0.150 & -0.117 & 0.324 \end{vmatrix}$$

and the estimated variance–covariance matrix is:

$$\text{(D.2)} \qquad V[\epsilon] = \begin{vmatrix} 7.06 & 2.37 & 2.47 & 0.90 \\ 2.37 & 3.30 & 0.90 & 0.34 \\ 2.48 & 0.90 & 7.06 & 2.37 \\ 0.90 & 0.34 & 2.37 & 3.30 \end{vmatrix}$$

Table D1 shows the results of simulations based on these estimates of the Solow residuals (Case 1) and the effects of adding taste shocks (Cases 2 through 7). Table D2 provides a catalog of the various taste shocks used in the simulations.

The results based on first–differenced data are somewhat different from the Hodrick–Prescott filtered results. The standard deviation of aggregate output is at the upper end of the two–standard deviation band with disturbances to productivity alone while the standard deviation of nontraded–good output is above the band. Similarly, the standard deviation of aggregate labor already exceeds the upper limit of the band. The correlations between relative prices and quantities are well below the data and again, the correlation between consumptions across countries is too large.

Cases 2 through 7 consider taste shocks of roughly the same types discussed in the text. The simulation results reveal that these types of demand shocks introduce a trade–off: taste shocks improve the correlations between prices and quantities, raise the standard deviation of consumption and reduce the cross–country consumption correlation. When the shocks are large enough to produce these effects, however, the standard deviations of labor and output exceed the two–standard deviation band, the correlation between quantities across sectors are too low.

Table D1: **Simulation Results**

Standard Deviations:

Variable	Data:		Case 1 Model:	Case 2 Model:	Case 3 Model:	Case 4 Model:
Aggregate:						
Output:	2.59	(2.20, 2.98)	2.84	2.86	2.88	2.86
Capital:	2.50	(1.56, 3.44)	2.28	2.49	2.44	2.41
Labor:	1.49	(0.83, 2.15)	2.61	2.75	2.79	2.64
Investment:	5.70	(4.36, 7.04)	7.55	7.63	7.56	7.79
Consumption:	2.15	(1.69, 2.61)	1.32	1.61	1.47	1.57
Traded Good Sector:						
Output:	3.79	(2.84, 4.74)	4.19	4.25	4.31	4.21
Capital:	2.22	(2.03, 2.41)	3.38	3.46	3.52	3.41
Labor:	2.07	(1.16, 2.98)	2.28	2.61	2.52	2.32
Investment:	7.13	(5.21, 9.05)	12.49	12.55	12.53	12.51
Consumption:	2.81	(2.23, 3.39)	1.55	3.06	2.33	1.56
Nontraded Good Sector:						
Output:	1.87	(1.38, 2.36)	2.77	2.80	2.77	2.81
Capital:	3.17	(1.80, 4.54)	2.48	2.54	2.48	2.67
Labor:	1.26	(0.77, 1.75)	1.49	1.56	1.50	1.71
Investment:	6.13	(5.02, 7.24)	6.80	6.86	6.80	7.40
Consumption:	1.68	(0.99, 2.37)	1.50	1.52	1.50	2.25
Domestic Correlations:						
Corr(C,Y):	0.84*	(0.80, 0.88)	0.89	0.82	0.87	0.78
Corr(I,Y):	0.80	(0.70, 0.89)	0.97	0.94	0.96	0.93
Corr(CT,CNT):	0.75	(0.60, 0.90)	0.40	0.23	0.28	0.27
Corr(YT,YNT):	0.64	(0.42, 0.87)	0.30	0.28	0.29	0.30
Corr(APL,Y):	0.70	(0.53, 0.77)	0.25	0.23	0.20	0.27
Corr(N,Y):	0.67	(0.52, 0.82)	0.92	0.88	0.91	0.90
Domestic Price–Quantity Correlations:						
Corr(PN/PT,CN/CT):	−0.28*	(−.67, 0.11)	−1.00	−0.64	−0.81	−0.62
Corr(PN/PT,YN/YT):	−0.07	(−.27, 0.14)	−0.77	−0.70	−0.74	−0.73
International Variables:						
Correlations:						
Corr(Y,Y*)	0.64	(0.51, 0.77)	0.51	0.47	0.48	0.51
Corr(C,C*)	0.40	(0.18, 0.62)	0.71	0.33	0.50	0.50
Corr(S,I)	0.78	(0.67, 0.90)	0.87	0.83	0.83	0.88
Corr(TB,Y)	−0.25	(−.44, −.06)	−0.49	−0.51	−0.51	−0.49
Corr(CA,Y)	−0.31*	(−.59, −.04)	−0.40	−0.42	−0.42	−0.40
Standard Deviations:						
s.d.(TOT)	5.06	(4.19, 5.93)	2.05	2.66	2.35	2.31
s.d.(TB)	7.72	(4.57, 10.87)	0.62	0.67	0.66	0.62
s.d.(CA)	6.02	(4.08, 7.96)	3.69	4.29	4.18	3.70

Table D1: **Simulation Results** (cont)

Standard Deviations:

Variable	Data:		Case 1 Model:	Case 5 Model:	Case 6 Model:	Case 7 Model:
Aggregate:						
Output:	2.59	(2.20, 2.98)	2.84	2.87	2.88	2.95
Capital:	2.50	(1.56, 3.44)	2.28	2.56	2.67	2.75
Labor:	1.49	(0.83, 2.15)	2.61	2.71	2.75	3.10
Investment:	5.70	(4.36, 7.04)	7.55	7.88	8.03	7.59
Consumption:	2.15	(1.69, 2.61)	1.32	1.75	1.93	1.70
Traded Good Sector:						
Output:	3.79	(2.84, 4.74)	4.19	4.24	4.23	4.34
Capital:	2.22	(2.03, 2.41)	3.38	3.51	3.56	3.55
Labor:	2.07	(1.16, 2.98)	2.28	2.46	2.38	2.55
Investment:	7.13	(5.21, 9.05)	12.49	12.69	12.77	12.54
Consumption:	2.81	(2.23, 3.39)	1.55	2.44	2.52	2.39
Nontraded Good Sector:						
Output:	1.87	(1.38, 2.36)	2.77	2.84	2.83	3.23
Capital:	3.17	(1.80, 4.54)	2.48	2.73	2.79	2.95
Labor:	1.26	(0.77, 1.75)	1.49	1.89	1.81	2.30
Investment:	6.13	(5.02, 7.24)	6.80	7.34	7.44	6.99
Consumption:	1.68	(0.99, 2.37)	1.50	2.30	2.31	2.25
Domestic Correlations:						
Corr(C,Y):	0.84*	(0.80, 0.88)	0.89	0.74	0.71	0.87
Corr(I,Y):	0.80	(0.70, 0.89)	0.97	0.90	0.87	0.95
Corr(CT,CNT):	0.75	(0.60, 0.90)	0.40	0.20	0.44	0.19
Corr(YT,YNT):	0.64	(0.42, 0.87)	0.30	0.28	0.30	0.20
Corr(APL,Y):	0.70	(0.53, 0.77)	0.25	0.27	0.26	0.11
Corr(N,Y):	0.67	(0.52, 0.82)	0.92	0.88	0.86	0.89
Domestic Price–Quantity Correlations:						
Corr(PN/PT,CN/CT):	−0.28*	(−.67, 0.11)	−1.00	−0.46	−0.63	−0.60
Corr(PN/PT,YN/YT):	−0.07	(−.27, 0.14)	−0.77	−0.68	−0.71	−0.66
International Variables:						
Correlations:						
Corr(Y,Y*)	0.64	(0.51, 0.77)	0.51	0.50	0.50	0.42
Corr(C,C*)	0.40	(0.18, 0.62)	0.71	0.34	0.26	0.29
Corr(S,I)	0.78	(0.67, 0.90)	0.87	0.86	0.87	0.83
Corr(TB,Y)	−0.25	(−.44, −.06)	−0.49	−0.49	−0.50	−0.53
Corr(CA,Y)	−0.31*	(−.59, −.04)	−0.40	−0.40	−0.41	−0.42
Standard Deviations:						
s.d.(TOT)	5.06	(4.19, 5.93)	2.05	2.51	2.60	2.47
s.d.(TB)	7.72	(4.57, 10.87)	0.62	0.64	0.65	0.73
s.d.(CA)	6.02	(4.08, 7.96)	3.69	3.90	3.87	4.18

Table D2: **Technology and Taste Shocks used in Simulations**
(First–Differenced Data)

Case 1: Solow Residuals only

Variance–Covariance Matrix of Productivity Shocks:

$$\begin{vmatrix} 7.06 & 2.37 & 2.48 & 0.90 \\ 2.37 & 3.30 & 0.90 & 0.34 \\ 2.48 & 0.90 & 7.06 & 2.37 \\ 0.90 & 0.34 & 2.37 & 3.30 \end{vmatrix}$$

Autocorrelation Matrix of Productivity Shocks:

$$\begin{vmatrix} 0.231 & -0.412 & 0.090 & -0.057 \\ -0.117 & 0.324 & -0.081 & 0.150 \\ 0.090 & -0.057 & 0.231 & -0.412 \\ -0.081 & 0.150 & -0.117 & 0.324 \end{vmatrix}$$

Case 2: Taste Shocks for Home–Produced Traded Good:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 7.06 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.750 & 0.000 & 0.000 \\ 0.000 & 0.750 & 0.000 \\ 0.000 & 0.000 & 0.750 \end{vmatrix}$$

Case 3: Small Taste Shocks for Home–Produced Traded Good:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 0.071 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.995 & 0.000 & 0.000 \\ 0.000 & 0.995 & 0.000 \\ 0.000 & 0.000 & 0.995 \end{vmatrix}$$

Case 4: Taste Shocks for Nontraded Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.300 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.324 \end{vmatrix}$$

Case 5: Taste Shocks to Home–Produced Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 7.055 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 3.300 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.500 & 0.000 & 0.000 \\ 0.000 & 0.500 & 0.000 \\ 0.000 & 0.000 & 0.500 \end{vmatrix}$$

Case 6: Taste Shock to Home–Produced Goods, Correlated across goods

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 7.055 & 0.000 & 2.411 \\ 0.000 & 0.000 & 0.000 \\ 2.411 & 0.000 & 7.055 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.500 & 0.000 & 0.000 \\ 0.000 & 0.500 & 0.000 \\ 0.000 & 0.000 & 0.500 \end{vmatrix}$$

Case 7: Small Taste Shocks to Home–Produced Goods:

Variance–Covariance Matrix of Preference Shocks:

$$\begin{vmatrix} 0.071 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.033 \end{vmatrix}$$

Autocorrelation Matrix of Preference Shocks:

$$\begin{vmatrix} 0.995 & 0.000 & 0.000 \\ 0.000 & 0.995 & 0.000 \\ 0.000 & 0.000 & 0.995 \end{vmatrix}$$

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